Soumi-NPP VIIRS Radiometric Performance Validation using Lunar Band Ratio Time Series

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Abstract

Operational radiometric calibration of reflective solar bands (RSBs) of Suomi-NPP VIIRS relies on using onboard Solar Diffuser (SD) together with Solar Diffuser Stability Monitor (SDSM). As an independent validation of RSB calibration of VIIRS, lunar calibration is employed through observing moon in Earth View during scheduled spacecraft maneuver with lunar phase being nearly the same. These lunar calibrations often rely on using lunar irradiance models and it requires the model to be highly accurate.

Here, we present a simple lunar band ratio (LBR) approach to trend radiometer stability of VIIRS so that the usage of lunar irradiance model is not required. Using scheduled lunar observations, digital numbers (DNs) of the lunar signal are aggregated in each band after the removal of bias. One of the most stable bands such as M4 is chosen as the reference band for calculating the band ratios.

The LBR analysis reveals that M6 and M7 degrade the fastest and agrees well with the trending independently determined from onboard solar diffuser ratios. For stable bands such as M2-M4 of VIIRS, the variation range of M2/M4 and M3/M4 are all within 0.5%, indicating the LBR can reveal the sub percent band to band stability. It is demonstrated that long-term stability monitoring of VIIRS solar bands using LBR is an important part of the VIIRS lunar calibration and can reveal the relative degradation of instruments.

Introduction

- VIIRS scheduled lunar observations are performed approximately monthly.
  - ✓With the roll angle limitation between 0 to -14 degrees for safety.
- Lunar roll maneuver views the moon in the day side through the earth view sector near the nadir angle as shown in Figure 1.
- The dual gain bands are set to high gain mode during the collection.
- For radiometric stability and repeatability, the lunar phase angles are maintained between -51.1 to -50 degrees.
  - ✓Negative phase angle means that VIIRS views waxing moon.
  - ✓Initially, phase angle limit was from -56 deg to -55 deg in the first three scheduled lunar observations [1].

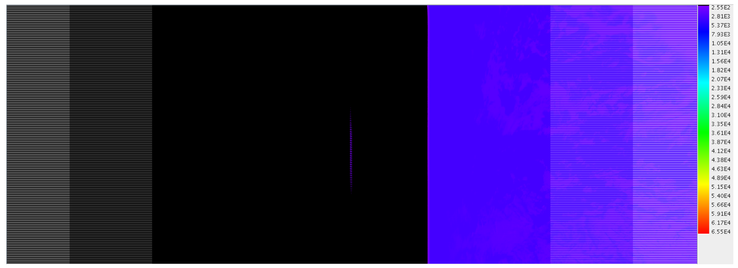

Figure 1. VIIRS band 1 image of the scheduled lunar collection on November 23rd 2012.

Data Sets

- VIIRS scheduled lunar observation data: 15 collections listed in Table 1.
- NASA LAADS (L1 Atmospheric Archive Distribution System) provides Verified Decompressed Raw Instrument Packets 5-min L0 RDR (vRDR).

Table 1. VIIRS scheduled lunar collection list

Date	Target time	Roll angle	Date	Target time	Roll angle
4/2/2012	23:05:11	-3.989	10/14/2013	21:39:19	-1.305
5/2/2012	10:20:06	-3.228	11/13/2013	6:57:41	-7.981
10/25/2012	6:58:15	-4.048	12/12/2013	19:35:46	-9.438
11/23/2012	21:18:20	-9.429	1/11/2014	9:59:45	-6.727
12/23/2012	15:00:50	-7.767	2/10/2014	5:34:12	-3.714
2/21/2013	9:31:25	-1.712	3/12/2014	1:11:43	-3.945
3/23/2013	3:29:00	-3.32	4/10/2014	20:53:15	-4.977
4/21/2013	19:47:54	-3.882			

Data Processing

- Lunar Band Ratio (LBR) calculation
  - ✓This methodology was originally developed and applied to monitor long-term normalized difference vegetation index (NDVI) stability for AVHRR [2].
  - ✓From the vRDR data sets, lunar area is properly trimmed including deep space in each band as shown in Figure 2.
  - ✓Before summation of the all the DN values, bias level is calculated and removed in each line by the averaged value from either sides of the moon.
  - ✓Lunar Band Ratios (LBR) are calculated by reference band M4 as shown in following equation.

$$LBR_{band} = \frac{\sum_{pixels}\left(DN_{band,pixel} - \langle bias\rangle_{band,line}\right)}{\sum_{pixels}\left(DN_{band\ M4,pixel} - \langle bias\rangle_{band\ M4,line}\right)}$$

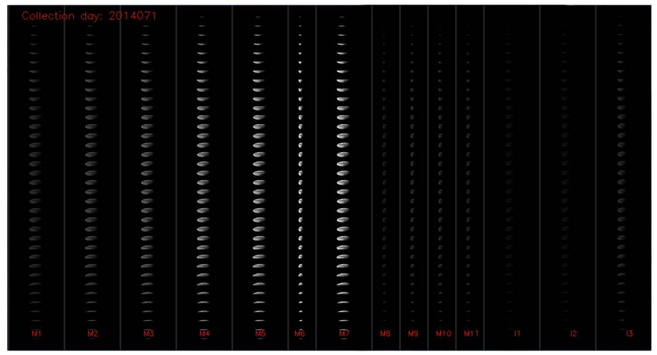

Figure 2. VIIRS trimmed lunar images in the reflective solar bands on March 12th 2014.

- Operational F factors are shown in Figure 3.
  - ✓The band M4 provides reasonably stable F factors over the VIIRS lifetime.
  - ✓The F factors are normalized by band M4 before comparing the LBR.

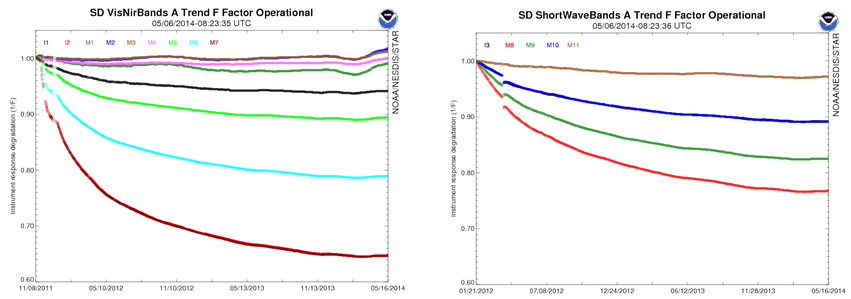

Figure 3. VIIRS operational F factors form VISNIR and short wave bands. These plots are taken from NOAA ICVS VIIRS long-term monitoring (LTM) website at http://www.star.nesdis.noaa.gov/icvs/status_NPP_VIIRS.php

Results and Analysis

- The LBRs versus SD F factor Ratios normalized by band M4 (Figure 4)
  - ✓The LBRs are normalized by the first scheduled lunar collection on 4/2/2012.
- VisNIR bands M1~M4 (400 to 600 nm)
  - ✓The LBRs are following the annual oscillation pattern but not as strong as F factor ratios.

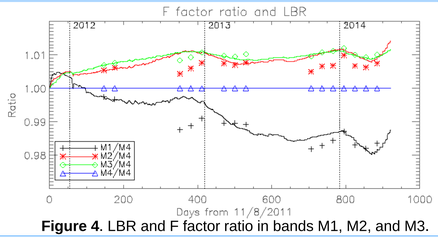

Figure 4. LBR and F factor ratio in bands M1, M2, and M3.

- VisNIR bands M5, M6, M7, I1 and I2 (Figure 5)
  - – The LBRs are following general F factor ratio trends.
  - – Differences between LBRs and F factor ratios are growing.
    - With time and center wavelength
  - – I2 and M7 ratios are almost identical.
- S/WMIR bands M8~M11 and I3 (Figure 6)
  - – There is no SD degradation applied in these bands.
  - – There are noticeable differences between F factor ratios and LBR.
- I2/M7 and I3/M10 ratios consistency (Figure 7)
  - – The LBRs and F factor ratios are consistent approximately within 0.2%.
- LBR / F factor ratio @ Lunar collection plot (Figure 8)
  - – The differences are increasing by time.
  - – With wavelength dependency.
- Wavelength dependency of LBR / F factor ratio (Figure 9)
  - – Used results on 3/12/2014 (2nd from the last).
  - – Ratios are increasing in the M5 ~ M8 wavelength range below 1μm bands.
  - – Ratios are decreasing in the short wave IR bands.

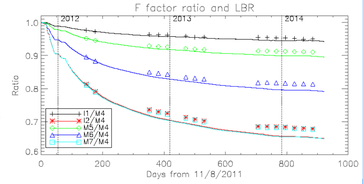

Figure 5. LBR and F factor ratios in bands M5, M6, M7, I1, and I2.

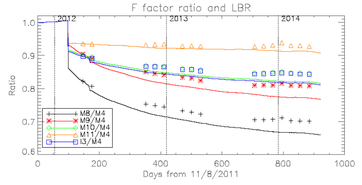

Figure 6. LBR and F factor ratios in bands M8~M11 and I3.

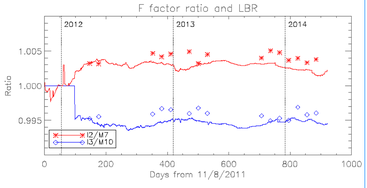

Figure 7. I2/M7 and I3/M10 consistency

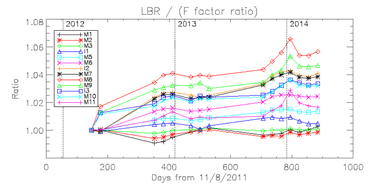

Figure 8. LBR / F factor ratio at lunar collection time

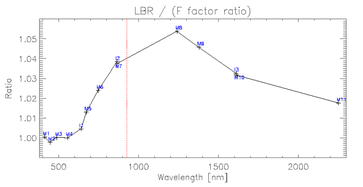

Figure 9. Wavelength dependency of LBR / F factor ratio using collection on 3/12/2014

Summary

- The LBR method is developed and applied to measure relative accuracy of VIIRS radiometric calibration coefficients (F factors).
- The LBRs are generally following the annual oscillation pattern of the F factor ratio within 0.5% especially in the bands M2 and M3.
  - ✓Growing differences over time are observed In bands of M5, M6, M7, I1 and I2.
- The S/WMIR band LBRs also suggest time dependent ratio differences.
- The direct ratios of I2/M7 and I3/M10 are very consistent within 0.2% in both LBRs and F factors.
- Strong wavelength dependencies are observed in longer wavelength bands beyond M5 at 672nm.
- The LBR demonstrated the radiometric stability and consistency in short wavelength bands in M1, M2, M3, and I1.

Reference

[1] J. Sun, X. Xiong, J. Butler, “NPP VIIRS On-Orbit Calibration and Characterization Using the Moon,” SPIE 2012: San Diego, CA; U.S.

[2] C. Cao, E. Vermote, X. Xiong, “Using AVHRR lunar observation for NDVI long-term climate change detection,” JGR, Vol. 114, D20105, 2009.